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METHOD AND APPARATUS FOR DETERMINING AND CORRECTING FOR ILLUMINATION VARIATIONS IN A DIGITAL PROJECTOR

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METHOD AND APPARATUS FOR DETERMINING AND CORRECTING FOR ILLUMINATION VARIATIONS IN A DIGITAL PROJECTOR

FIELD OF THE INVENTION

The present invention relates to display devices, and more particularly to methods and apparatus for correcting for variations in the display devices.

BACKGROUND OF THE INVENTION

Digital projection systems can exhibit variations in gain and intensity (offset) from pixel to pixel. These variations can be due to variations in the driving electronics, the light modulator, the projection optics, the display screen, and the illumination optics. Electronic systems can be developed to correct for the variations by applying gain and offset correction values to each pixel. US Patent No. 6,061,102 issued May 9, 2000 to Sheppard et al. shows a target brightness map that is generated for each of a plurality of preselected shading application points and the target brightness map is used to correct the input signal to the display to remove variations in the display. The shading process is automatically performed during projector setup.

One problem with this approach is that the Sheppard et al. device uses a CCD sensor wherein each pixel in the sensor senses a large number of pixels in the display and is therefore unable to correct for variations in individual pixel intensity. There is a need therefore for an improved method and apparatus for correcting variations in display pixel intensity that avoids the problems noted above.

SUMMARY OF THE INVENTION

The need is met according to the present invention by providing a method of correcting pixel by pixel variations in a display, the method including the steps of creating a defect map of pixel intensity offsets for the display; correcting an input signal according to the defect map; and displaying the corrected input signal on the display, wherein the offset defect map is created by

modulating a pixel in the display at a predetermined rate at a predetermined intensity; sensing the display with a photosensor to generate a sensed signal; demodulating the signal with a synchronous demodulator at the predetermined rate to produce a demodulated signal representing a sensed intensity; and employing the sensed intensity and the predetermined intensity to generate a correction offset.

ADVANTAGES

The method and apparatus of the present invention has the advantage of correcting for each pixel of the display. The components required are low cost, and correction data is collected for the entire electro-optical projection system.

BRIEF DESCRIPTION OF THE DRAWINGS

Fig. 1 is schematic diagram of a projection display system incorporating the correction method of the present invention;

Fig. 2 is a graph illustrating the computation of a gain correction value according to one embodiment of the present invention;

Fig. 3 is a flow chart illustrating the correction method according to the present invention; and

Fig. 4 is a flow chart illustrating the step of creating a defect map according to the present invention.

DETAILED DESCRIPTION OF THE INVENTION

The present invention collects data on pixel gain and intensity using a simple sensor that collects light from the entire projected image. To obtain the correction data, all pixels are driven to black, or a predetermined level except for the pixel under observation. The pixel under observation is driven at a predetermined frequency that is preferably some fraction of the refresh rate of the display. A photosensor senses the entire display to produce a signal representing the light from the pixel. To increase sensor accuracy according to the present

invention, the sensor is equipped with a synchronous demodulator that demodulates the signal at the predetermined frequency. The sensed intensity and the predetermined intensity are employed to generate an offset correction. The process is repeated for a plurality of intensities to generate a gain correction. The process is repeated for all pixels of the modulator and correction values created.

Referring to Fig. 1, a projection display **10** according to the present invention includes a light source **12**, such as a xenon projection lamp. The light from the light source **12** is conditioned by light source optics **14** to improve uniformity and color balance, remove heat, and concentrate the light onto the surface of a light modulator **16**, such as the JVC DILA reflective liquid crystal light modulator. Light reflected from the light modulator **16** is directed to a display screen **20** by projection optics **18**. Drive electronics **22** applies a corrected input signal to the light modulator **16**. Correction electronics **24** applies a pixel by pixel correction to the input signal to correct for pixel by pixel variations in gain and offset. The corrections are stored in a defect map contained in a memory **26** such as a nonvolatile RAM.

According to the present invention, the corrections stored in the defect map are generated by driving one pixel at a time at a predetermined frequency. The signal for driving the pixel is generated, for example by a programmed microprocessor **28**. A photosensor **30** is directed at the display screen **20**, or alternatively at the projection optics **18** to generate a sensed signal. The sensed signal is detected by a synchronous detector **32** and converted to a digital signal by analog to digital converter **34**. The digital detected signal is supplied to the microprocessor **28** where an intensity offset correction **O** is generated by comparing the signal sent to drive the pixel with the sensed demodulated signal. By driving the pixel at a predetermined frequency and sensing the detected signal with a synchronous demodulator at the predetermined frequency, the relatively weak signal produced by a single pixel can be efficiently detected in the presence of flare light and other noise that may corrupt the signal. The offset correction value **O** is recorded in the defect map. When the display is

operating, the offset correction value **O** is added to the input pixel values that correspond to the pixels position on the display.

Referring to Fig. 2, if the pixels in the display have gain variations, a gain correction value can also be generated by driving a pixel at several different input intensity levels and sensing the signal at each intensity level to produce a corresponding plurality of output values **31**. A line is fit through the output values **31** to produce a gain curve **33**. The slope $\mathbf{S_1}$ of the gain curve **33** is the gain of the pixel. The ratio of the slope $\mathbf{S_2}$ of an ideal gain curve **35** to the slope $\mathbf{S_1}$ of the sensed gain is computed as a gain correction value **G** for the pixel. The gain correction value **G** is recorded in the defect map. When the display is operating, the input pixel values are multiplied by the gain correction values **G** that correspond to the pixels position on the display.

Referring to Figs. 3 and 4, a method of using the apparatus of Fig. 1 according to the present invention will be described. First a defect map is created **36** that contains the corrections to be applied to all of the pixels of the display. The defect map is then used to correct **38** each pixel of the input signal to the display. Finally the corrected input signal is displayed **40**. As shown in Fig. 4, the defect map is created by modulating **42** a single pixel at a predetermined rate and intensity while keeping all other pixels at zero or some predetermined level. The display is sensed **44** with a photosensor to generate a signal. The sensed signal is demodulated **46** with a synchronous demodulator, and a correction offset is generated **48** from the demodulated signal. The steps are then repeated **50** for every pixel in the display.

For simplicity, the method has been described with respect to one channel, however it will be understood that the method can be applied to each channel of a color display device. It will also be understood that a cluster of pixels can be modulated rather than a single pixel when typical defects in the display occur over regions that are greater than one pixel, thereby reducing the time to characterize the display.

The invention has been described in detail with particular reference to certain preferred embodiments thereof, but it will be understood that variations and modifications can be effected within the spirit and scope of the invention.

PARTS LIST

10	projection display
12	light source
14	light source optics
16	light modulator
18	projection optics
20	display screen
22	drive electronics
24	correction electronics
26	memory
28	programmed microprocessor
30	photosensor
31	output values
32	synchronous detector
33	gain curve
34	analog to digital converter
35	ideal gain curve
36	create defect map step
38	correct signal step
40	display corrected signal step
42	modulate single pixel step
44	sense display step
46	demodulate signal step
48	generated correction offset step
50	repeat for each pixel step